THE SMITHSONIAN 'SOLAR CONSTANT' EXPEDITION TO CALAMA, CHILE

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As early as 1903 the observations of the Smithsonian Astrophysical Observatory suggested the view that the solar radiation varies over a range of several per cent within intervals as short as a few days or weeks. We were measuring the radiation of the sun at the earth's surface. The measurements comprised determinations of the heating effect of the solar rays on the blackened surface of the pyrheliometer, which measures all rays of the spectrum as found in 'white light,' and also the heating effects at all parts of the solar spectrum as detected by the bolometer, including ultra-violet, visible and infra-red rays. We measured at intervals on every clear day as the sun declined from high altitudes near the zenith to low altitudes near the horizon. Thus the rays measured passed through longer and longer paths, according to the obliquity with which they crossed the atmospheric layers, and consequently they grew weaker and weaker as the sun declined lower and lower. From the spectro-bolometric measurements, standardized to calories by aid of the simultaneous pyrheliometer measurements and reduced to zero atmospheric absorption by the method of Langley we thus determined the intensity of solar radiation as it would be outside the atmosphere at mean solar distance. This has been called the solar constant of radiation. Its average value is about 1.93 calories per square centimeter per minute.

As I have said the results of 1903 at Washington indicated variations of this so-called constant over a range of nearly 10%. Owing to the prevalence of clouds at Washington all too few observations were available. Nevertheless when we compared such as we had with the anomalies of temperature of the North Temperate Zone as represented by meteorological observations at 89 stations, all regions showed a variation of temperature nearly parallel to, and of a proper magnitude to correspond with, the supposed variations of the sun.

In 1905 we transferred the observing to Mount Wilson, California, and with the exception of 1907 we have observed the 'solar constant,' in that relatively favorable place, usually from June to October of each year. The results have confirmed the apparent variability of the sun. It is impossible to go outside the atmosphere to observe, and we feared that the apparent variability of the sun might have been really due to defects in our estimation of the losses in the atmosphere. To check our work as far as possible we observed in 1908, 1909, and 1910 from the summit of Mount Whitney (4420 meters) the highest peak in the (older) United States. No error dependent

on altitude appeared. In 1914 we sent an automatic recording pyrheliometer by sounding balloon to 25,000 meters altitude. The result obtained was trustworthy and agreed with what we expected. All these checks confirmed the accuracy of our work and strengthened our belief in the solar variability.

Meanwhile in 1911 and 1912 I had observed in Algeria while my colleagues observed in California. Unfortunately for the proof of solar variability 1911 was cloudy and 1912 was the year the air was charged with volcanic dust by the great volcanic eruption of Mount Katmai, June 6, 1912. Nevertheless despite this handicap the results left little reasonable doubt that the sun is variable. High 'solar constant' values at Bassour, Algeria, coincided with high values at Mount Wilson, California, and vice versa, and equal increments of radiation were found at the two stations independently, notwithstanding that they are separated by one-third the earth's circumference.

In 1913 and subsequently the proof of solar variability was rendered impregnable. We investigated daily the distribution of radiation over the solar image formed by our tower telescope on Mount Wilson. The sun's image is, as you know, unequally bright at centre and edges, so that the curve of its intensity along a diameter takes the form of the letter U inverted. The steepness of the curves of the U varies with wave-length. But we found also that it varies from day to day, and that the variations are such that a greater contrast of brightness between center and edge occurs when the solar radiation as a whole is found to be diminished and vice versa. I suppose the outer layers of the sun vary in transparency. When more opaque they diminish the 'solar constant' but as the effect is greatest near the limb of the sun where the oblique path of the ray in the solar layers is greatest, the result is also to increase the contrast. At all events we have found a true variation of the sun, independent of the earth's atmosphere, which coincides in time of its fluctuations with the observed changes of the 'solar constant.'

Professor Pickering had kindly undertaken pyrheliometer measurements at Arequipa, Peru. These were carried on from 1912 to 1917. They tended to confirm in the more outstanding features the variation of the sun observed at Mount Wilson.

Dr. L. A. Bauer, whose remarkable campaign of magnetic observations lends lustre to the science of our country, has investigated certain minute disturbances of terrestrial magnetism for which no cause had been assigned. He finds them to be closely correlated with the variations of solar radiation we have observed.

Dr. H. H. Clayton, formerly of Blue Hill Meteorological Observatory, now of the Argentine Meterological Service, has investigated the variations of terrestrial atmospheric temperature and pressure for nearly fifty stations in all parts of the earth. He finds a close correlation of these meteorological variations with the irregular variations we have observed in solar radiation. Equatorial stations show a direct correlation in temperature. That is high solar radiation is followed by high temperature and vice versa. Many tem-

perate zone stations show opposition of variation. Polar stations show direction variation. If these results shall be confirmed and enlarged they bid fair to aid in actual weather forecasting, for the changes are by no means small.

In view of the scientific and utilitarian interest associated with the variability of the sun, I have long desired that several cloudless observing stations might take up 'solar constant' work. In 1914 I made a trip to Australia expecting that the Australian Government would take it up. This hope was frustrated by the war.

In 1916 Secretary Walcott appropriated from the income of the Hodgkins Fund to equip and maintain for several years such a station in South America, but owing to the war it was temporarily located in the North Carolina mountains in 1917. The station proved very cloudy, and now it has proved possible though very expensive to go to Chile.

After correspondence with the South African, Indian, Argentine and Chilean meteorological services I became convinced that near the nitrate desert of Chile is to be found the most cloudless region of the earth easily available. Dr. Walter Knoche of Santiago has most kindly furnished two years (1913 and 1914) of unpublished daily meteorological records for a number of Chilean stations. In his judgment and mine the best is Calama on the Loa River, Lat. S. 22° 28′, Long. W. 68° 56′, Altitude 2250 meters. For the two years the average number of wholly cloudless days is at 7 a.m. 228; 2 p.m., 206; 9 p.m., 299; and of wholly cloudy days, none. The precipitation is zero; wind seldom exceeds 3 on a scale of 12; temperature seldom falls below 0° or above 25°C.

Our expedition, Director Alfred F. Moore, Assistant Leonard H. Abbot, reached Calama June 25, 1918, equipped with a full spectro-bolometric, pyrheliometric, and meteorological outfit of apparatus, as well as with books, tools, household supplies, and everything which we could furnish to make the work successful and life bearable. We are under great obligations to the Chilean Government for facilitating the expedition in many ways, and to the Chile Exploration Company who have given the expedition quarters and observing station at an abandoned mine near Calama. Many others in Antofagasta, Chuquicamata and Calama have been of great assistance.

The apparatus is set up in an adobe building about 30 feet square, in which the observers also have sleeping apartments. A 15-inch two-mirror coelostat reflects the solar beam to the slit of the spectro-bolometer. We use a Jena ultra-violet crown glass prism and speculum metal mirrors in the spectroscope. The linear bolometer is in vacuum, and constructed in accord with complete theory for greatest efficiency. Its indications as measured by a highly sensitive galvanometer are recorded photographically on a moving plate which travels proportionally to the movement of the spectrum over the bolometer. Successive bolometric energy spectrum curves each occupying 8 minutes of time are taken from early morning till the sun is high and are

thus recorded on the plate. Their intensity indications at 40 spectrum positions are reduced by aid of a special slide rule plotting machine.

A pair of silver disk pyrheliometers is read simultaneously with each spectro-bolographic determination. Measurements of humidity, temperature, and barometric pressure accompany the bolometric observations. Also a pyranometer is employed to determine the total sky radiation.

The young men find pleasant companions at the great copper mine at Chuquicamata. At present they are boarding with a Chilean family at Calama, but as both are good cooks they may wish to board themselves. The railway and the river both pass the town of Calama, so that there is no such desert isolation as might be feared. To the east are the Andes Mountains. The peaks in that neighborhood rise to 16,000 or 17,000 feet. Some are volcanic but none of these are very near.

We hope the work will be continued for several years at least, and that nearly daily observations may be obtained. The application of the results to meteorology is something which may prove to have great possibilities. To exploit them we must first possess a long and nearly unbroken series of solar radiation observations.

MAROON—A RECURRENT MUTATION IN DROSOPHILA[1]

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The recessive eye-color 'maroon' was one of the early mutations in Drosophila (found March 13, 1912). This eye-color was found in a stock culture of wild flies, and was at first supposed to be a new appearance of the recessive mutation 'purple' discovered about a month earlier. Genetic tests (crosses between the two lines, etc.) showed that the new color was not the old purple, but was a new mutation almost identical with purple in appearance but entirely independent in origin and inheritance. This was the first of our now numerous cases of eye-color 'mimics,' in which two distinct genes produce practically the same somatic effect.

During the six months following the discovery of purple and maroon there were thirteen recorded appearances or 'purple' eye colors, which constituted our most striking 'mutating period' of 'epidemic of mutation.' Of these new 'purples,' tests showed that the first, fifth, sixth, and thirteenth were maroon, while the rest were true purple. A study of the pedigrees showed that these maroons had come from two independent occurrences of the maroon mutation, while the true purples likewise came from at least two separate acts of mutation. Maroon has reappeared independently on two subsequent occasions, so that this particular mutative process has occurred at least four times. The